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The Effects of Active Recovery during High Intensity Resistance Training on Lactate Clearance in Collegiate Athletes

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ON LACTATE CLEARANCE IN

COLLEGIATE ATHLETES

By

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Abstract

Purpose: With the development of more intense and complex strength and conditioning programs, it is necessary to discover the best possible means of recovery during workout sessions to increase athletic performance. The objective of this study is to evaluate the effects of active recovery during the rest periods of a resistance training session on lactate clearance in varsity collegiate athletes. **Methods:** Twenty healthy varsity collegiate athletes age 18-22 yr participated in a collegiate strength and conditioning workout session. Participants were randomly divided into an active recovery group (A.R.) and a passive recovery group (P.R.). Both groups performed 5 exercises for 2 sets of 8 repetitions at 70% 1RM, with 3 minutes of recovery between each set. The exercises were performed in the following order: Power Clean, Barbell Squat, Barbell Bench Press, Barbell Bent-Over Row, and Kettlebell swings. A.R. consisted of cycling on a Monark cycle ergometer at minimum resistance at 60 rpm during each 3 minute rest period, while P.R. remained stationary for the duration of the rest period. The blood lactate levels were recorded during each 2^{nd} rest period utilizing finger prick blood analysis via Nova blood lactate analyzers. The changes in blood lactate were compared between A.R. and P.R. groups using a 5 x 2 repeated measures ANOVA statistical analysis. **Results:** The repeated measures ANOVA revealed no significant difference of blood lactate levels between groups overall during the workout session. However, the results yielded a strong trend between groups during the power clean exercise circuit; p=.053. **Conclusions:** There were no significant differences between A.R and P.R. groups during the overall resistance training session, but significant differences between

groups during power cleans, revealing that active recovery interventions may be beneficial if performed after more strenuous, full-body resistance training movements.

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Chapter I – Introduction

The majority of research on active recovery as an efficient tool during physical activity has revealed positive indications of improving athletic performance and decreasing vulnerability to sustaining injury (Cronin, Mohamad, Nosaka, 2012). Studies have related active recovery to proper warm-up protocols due to their similarity in usage of brief aerobic exercise. Proper warm-up procedures have always been important staples in many teams strength & conditioning programs, with constant focus on the best methods of increasing performance in the athletic arena during competition. Previous studies discovered how effective warm-up techniques composed of both aerobic exercise and stretching decreased the prevalence of injury due to the increases in muscle temperature resulting in enhanced elasticity of muscle tissue (McNair, Stanley, 1996). In addition, Safran et al. (1996) conducted a study experimenting with the effects of muscular temperature on muscular resiliency. The researchers discovered that increased muscular temperature may be beneficial in injury prevention by increasing elasticity and length to failure within exercising muscle fibers indicating further rationale for benefits of efficient warm-up routines (Safran et al., 1988).

In addition, many researchers have focused their energy into evaluating the relationship between muscular temperature and overall physical function and performance. Increases in muscular temperature have been found to be a well known determinant for skeletal muscle function, creating changes in force-velocity and maximal power output relationships (Bell, Ferguson, 2009). Findings from the research suggest that increased muscular temperature increases muscular mechanical efficiency, allowing individuals to engage in bouts of physical activity more efficiently, and for longer durations (Bell, Ferguson, 2009). A similar study by Gray et al. (2005) discovered that increased muscular temperature resulted in significantly improved ATP turnover rates for phosphocreatine utilization, glycolysis, and total anaerobic power compared to normal temperature levels, leading to considerably improved physical performance.

Key elements of proper warm-up techniques, aerobic activity in particular, has been well known to promote various components of physical activity including power output, and overall performance. Aerobic activity is most notable for improving metabolic factors during physical activity such as oxygen uptake, and blood lactate clearance which allow for increased performance during exercise (Cronin, Mohamad, Nosaka, 2012). Bogdanis et.al conducted a study analyzing the effects of active recovery during the interset periods of high intensity sprinting on a cycle ergometer. The findings of the research displayed significantly higher power output in the 2nd set of sprints in the group utilizing active recovery due to increased oxygen uptake levels which were not evident in the group utilizing passive recovery (Bogdanis, et. al, 1996). A similar study also revealed considerable results, revealing power output levels decreasing significantly faster in sprinters whom did not utilize active recovery methods during each resting stage of the workout component of the study (Connolly, Brennan, Lauzon, 2003).

Although it is notable that the popular research conveys active recovery's positive impact on athletic performance during bouts of high-intensity conditioning activities, there is a great need for analysis of its effects on resistance training athletes, both recreational and competitive. Numerous studies have examined active recovery's possible positive influence on resistance training performance. Corder et al. conducted research focusing on active recovery's impact upon blood lactate reduction, rate of perceived exertion, and performance during a session of resistance training. The researchers discovered significantly lower points of OBLA (Onset of Blood Lactate accumulation) in addition to increased performed repetitions of the barbell squat concluding that active recovery is the most efficient method of reducing blood lactate while also increasing performance during resistance training (Corder et al, 2000).

Aerobic activity has also been found to exhibit a positive impact upon neuromuscular fatigue during bouts of resistance training. Heavy resistance training activities have been shown to cause changes in maximal voluntary neural activation of exercised muscle groups, leading to decreases in maximal force and strength output (Hakkinen, 1993). Hakkinen's research revealed that heavy resistance training significantly impacts neuromuscular functioning leading to decreased force and neural activation capability. A recent research study analyzed how recovery from muscular fatigue during training may positively impact neuromuscular function, and thus promote athletic performance (Mika, Mika, Fernhall, Unnithan, 2007). Mika et. al analyzed the effects of stretching, active recovery, and passive recovery on muscular recovery after a leg extension exercise. The study's results displayed greater increases in motor unit activations of the quadriceps after using active recovery procedures consisting of light aerobic cycling for 5 minutes between each set (Mika, et. al, 2007). The findings of the research suggest that the implementation of active recovery sessions not only improve muscular metabolic function, but can also improve performance in avenues of neuromuscular function with increased motor unit function (Mika, et.al, 2007).

Active recovery involves performing light aerobic activity in between sets or repetitions of either high-intensity cardiovascular or resistance training. Aerobic activity is most notable for improving metabolic factors during physical activity such as oxygen uptake, and blood lactate clearance which allow for increased performance during exercise (Cronin, Mohamad, Nosaka, 2012). Though the research suggests that active recovery is indisputably one of the best tools for improving performance during shorts bouts of resistance training, it is still unclear as to the benefits to realistic strength & conditioning sessions. In addition, researchers are uncertain of active recovery's impact upon an athlete's level of activity during a normal daily routine and their total energy expenditure. Popular trends indicate that more athletic teams are taking part in high-resistance training protocols, consisting of explosive movements, full-body muscular utilization, and performing repetitions to muscular failure; all such condition factors of training that lead athletes to feelings of fatigue in their normal activities outside of athletics. In order to justify how active recovery during high intensity resistance training impacts total energy expenditure and levels of activity outside athletics, it is necessary to utilize Body Media Fit Accelerometers. Fruin, Rankin, 2004., conducted a study to validate the efficiency of Body Media Fit Accelerometers against the gold standards of energy expenditure measurement, doubly labeled water and indirect calorimetry during resting and exercise conditions. The researchers found that armbands provided valid and reliable estimates of total energy expenditure in young, normal weight adults (Fruin, Rankin 2004). A second study tested the ability of the armbands to assess the daily energy expenditure in older aged populations. The researchers findings revealed that the measurements from both doubly labeled water and the accelerometers were highly correlated, revealing the armbands to be reliable means of measuring energy expenditure (Mackey, et.al 2011). From the research, it can be concluded that the Body Media Fit

Accelerometers would be acceptable means of calculating energy expenditure in collegiate female athletes.

As fitness professionals, it is necessary to discover the best possible means of recovery during workout sessions to not only increase athletic performance, but the quality of life outside of athletics of collegiate athletes. As a result, the purpose of this study will be to determine the effects of active recovery during high-intensity resistance training on athletic performance and energy expenditure in collegiate athletes.

Statement of the Problem

Though the research suggests that active recovery is indisputably one of the best tools for improving performance during shorts bouts of resistance training, it is still unclear as to the benefits to realistic strength & conditioning sessions. Popular trends indicate that more athletic teams and recreational athletes alike are taking part in high-resistance training protocols, consisting of explosive movements, full-body muscular utilization, and performing repetitions to muscular failure. As fitness professionals, it is necessary to discover the best possible means of recovery during the interset periods of training to create increases in muscular hypertrophy, muscular strength, and muscular endurance to efficiently promote increased performance in recreational trained athletes. As a result, the purpose of this study will be to determine the effects of active recovery during the interset rest periods of high-intensity resistance training on lactate clearance.

Research Hypothesis

The researcher expects that the institution of active recovery during rest periods of a high-intensity resistance training program will improve athletic performance by eliciting lower blood lactate levels during a workout session.

Operational Definitions

An active recovery method will be instituted during each interset rest period of exercise during the high-resistance training protocol consisting of light cycling on a monark ergometer for three minutes during each rest period of each set of exercise. The final variable of rate of perceived exertion will be measured using a scale of 6-20, 6 representing minimal effort, and 20 representing maximal effort.

Assumptions

The researcher of the study can assume that the collegiate athletes in the study have prior experience in resistance training, and thus will be able to perform the repetitions using proper strength training form and technique. In addition, the weight training protocol is a familiar workout routine designed by the strength & conditioning coaches, implying that the athletes will perform to their maximum ability during testing. An additional assumption can be made that participants of the study will respond truthfully to questions regarding rating of perceived exertion to accurately assess levels of fatigue. The experimenter can also assume that the participants will be wearing the accelerometers correctly and for the complete duration of the study.

Limitations

This assumption may however present a limitation on the fact that all participants within the study may not put forth a maximum effort during the high-intensity resistance training program. The athletes participating in the study may also remove the accelerometer during the 72 hour data collection period, impeding full collection of data. In addition, the athlete may also refuse to undergo finger prick blood analysis for blood lactate testing during the weight training session.

Delimitations

In order to reduce the possibility of participants putting forth a lack of effort, it is necessary to delimit the study to collegiate athletes whom are currently supervised and coached by collegiate strength and conditioning coaches, in order to help ensure that maximum effort will be given during the weight training portion of the research study.

Chapter II - Review of the Literature

Most of the research in the field of strength & conditioning has focused on experimentation involving the manipulation of sets, repetitions, and workload. However, there has been minimal research involving the activity performed during the interest rest periods of resistance training (Cronin, Mohamad, Nosaka, 2012). Cronin, Mohamad, and Nosaka's (2012) research review suggests that performing light aerobic activity during the interset rest periods of resistance training may incur benefits including muscle hypertrophy, increase in strength & power output, mechanical performance, hormonal response, metabolic output, and neuromuscular recovery. The following literature review will have a divided focus on active recovery's impact on athletic performance, and related studies that suggest aerobic exercise during the interset periods of training may positively impact various physiological components.

More often than not, a proper warm-up protocol is a key factor in improving athletic performance and preventing injury. Most research studies have focused on changes in range of motion or displacement as the result of a warm-up procedures' efficiency, while offering no insight to the warm-up's effect on muscle and tendon stiffness during muscular contraction (McNair, Stanley, 1996). Effective warm-up activities composed of both aerobic exercise and stretching techniques have been shown to be efficient in decreasing the occurrence of strain related injuries by increasing the muscle temperature resulting in improved extensibility of the muscle tissue (McNair, Stanley, 1996.) The researchers of the study wanted to determine whether jogging, passive stretching, or combination of the two would produce an increase range of motion in the ankle joint, as well decrease the muscular stiffness of the plantar flexors (McNair, Stanley, 1996). The study's methods included a combination of three protocols by which each participant performed in a randomized order. The subjects consisted of 24 recreationally trained athletes (12 male, 12 female) who participated in organized sport for at least 1 to 3 times per week. The participants did not possess a specific stretching routine, however they did participate in light stretching activities prior to recreational athletic activity (McNair, Stanley, 1996).

The stretching protocol consisted of five 30 second static stretches with 30 second rests in between each set, with the stretches focus on the plantar flexors. The aerobic jogging protocol consisted of each participant running on a treadmill at 60% of their maximum heart rate for 10 minutes, while the combination protocol was composed of running prior to the stretching routine (McNair, Stanley, 1996). The subjects underwent the three warm-up protocols at the same time of day over a three day testing period, in which the dominant leg was utilized for recording results (McNair, Stanley, 1996). The researchers assessed the outcome of the experimentation by analyzing the dorsiflexion range of motion of the ankle, and the level of muscle stiffness. To assess the ankle range of motion, the researchers used a weight and pulley system by which the subject sat with the knee and ankle flexed to a 90 degree angle. With the addition of each weight plate (weighing approximately 1.8 kg), an electrogoniometer measured the angle of dorsiflexion in the ankle until it reached its maximal range of motion (McNair, Stanley, 1996). The researchers measured changes in muscle stiffness by using a damped oscillation technique that measures the rate of oscillatory decay (McNair, Stanley, 1996). The results of the study displayed that jogging was more effective than stretching in decreasing muscle stiffness. However, the stretching and combination protocols were more effective in increasing overall dorsiflexion range of motion in the ankle joint (McNair, Stanley, 1996). These results are pertinent to the current study because it is important to note that aerobic exercises such as jogging are an effective means in reducing muscle stiffness and promoting blood flow that may result in increased athletic performance.

There have many studies that have documented active recovery's positive effect on blood lactate removal rates, but limited research has actually looked into its impact upon power output and performance (Bogdanis, Graham, Lakomy, Louis, Nevill, 1996). Results from numerous studies suggest that bouts of active recovery during the inter sets of high intensity exercise may have beneficial effects compared with passive rest (Bogdanis, et al. 1996). The purpose of this study was to determine if active recovery performed during high intensity sprints would improve power output and the restoration of blood metabolites (Bogdanis, et al. 1996). The study included a total of 13 healthy recreationally trained males, with the average age of 25 years. The methods consisted of preliminary sprint practice sessions which included short duration sprints ranging 6- 10 seconds, and longer bouts of durations up to 30 seconds (Bogdanis, et al. 1996).

The researchers then measured each subject's VO2 Max using a Monark cycle ergometer to account for the rates of oxygen consumption and carbon dioxide expiration. At a separate time, the participants underwent submaximal cycling testing in order to accurately set the load for a 40% VO2 max intensity for the active recovery portions of the experimentation (Bogdanis, et al. 1996). Each primary testing session were separated by 1 weeks' time, consisting of two 30 second cycling ergometer sprints which were separated by a recovery period of 4 minutes. Following the longer sprints, a 6 second sprint was performed 11 minutes after the final 30 second sprint was performed (Bogdanis, et al. 1996). The recovery methods consisted of two protocols with the active recovery consisting of each participant pedaling backwards for the first and last 30 seconds of the recovery, and forwards for the 3 minutes in between at a resistance equivalent to their 40% VO2 max measurement (Bogdanis, Graham, Lakomy, Louis, Nevill, 1996). The second recovery method was more passive where the subject was instructed to rest seated on the cycle ergometer until the next sprint was performed. During the test, athletic performance variables including peak power output, maximum pedal speed, and average power output for each sprint were calculated (Bogdanis, et al. 1996).

The results of the study displayed that active recovery methods exhibited a significantly higher power output during the 2nd sprint than of that compared to the passive recovery. The researchers attributed this improvement to the higher power output generation during the first 10 seconds of the second sprint during the active recovery testing. The findings showed no significant differences in blood lactate levels, and PH, nor were there differences in arterial blood pressure and plasma volume between to the two recovery methods. But the results did show that heart rate and oxygen uptake between the two 30 second sprints was far greater in the active recovery testing compared to the passive recovery session. The researchers came to the conclusion that active recovery during rest periods can enhance muscular power output recovery between sets of sprints, leading to greater athletic performance. The effects of active recovery may be due to an increase in blood flow to the exercised muscle tissue that accelerates blood lactate buffering and reduces fatigue (Bogdanis, et al. 1996). This research is important to the present study because it displays the effects of light aerobic activity as active recovery to help promote increased athletic performance.

Conolly, Brennan, and Lauzon (2003) conducted a similar study analyzing the effects of active recovery on power output during repeated bouts of sprints via cycling. It is well known that high intensity exercise results in increased levels of lactate in the muscle tissue that disrupts the ability for muscle contraction, and leads to early fatigue during physical activity (Connolly, Brennan, Lauzon, 2003). Research studies show that the removal of lactate from the bloodstream results in increased ability to maintain performance during physical activity.

Due to the fact that many athletes train via high intensity training methods, it would be beneficial to find recovery methods that could increase performance during vigorous training sessions. The purpose of this study was to investigate the effects of active recovery during cycling sprints on peak power, average power, and blood lactate levels in healthy male athletes (Connolly, Brennan, Lauzon, 2003). The participants for the study consisted of seven recreationally active male cyclists with an average age of 21.8 ± 3.3 years. Each subject in the study underwent both active and passive recovery protocols during each cycling sprint session. Every trial was separated by one week to provide the most optimal results. The passive recovery procedure consisted of the subject remained immobile on the stationary bike for 2 minutes and 50 seconds before the next bout of cycling sprints. In contrast, the participants engaged in active recovery procedures pedaled at 80 rpm with 1 kg resistance before the start of the next maximal cycling sprint. The anaerobic sprint consisted of each subject completing a 3 minute warm-up at 1 kg of resistance before an all out fifteen-second sprint on the stationary cycle. Each participant completed a total of 6 sprints at 5.5 kg resistance with 3 minutes of recovery between each short period. All data collection was done using a Monark cycle ergometer in addition to Sports Medicine Industries Power software which calculated power values for each participant (Connolly, Brennan, Lauzon, 2003). Using a simple puncture method, blood samples were taken from each participant 2 minutes following each 15-second maximal sprint, and 5 minutes following the final set for blood lactate analysis. Results from the study displayed no significant differences in average peak power output across the trials between both active and passive recovery protocols (Connolly, Brennan, Lauzon, 2003). Further, the results displayed no significant differences for average power between the two recovery methods. However, there were significant results observed within the trials for both peak power and average power with both values decreasing with each sprint (Connolly, Brennan, Lauzon, 2003). Values recorded for the passive recovery protocol were decreased in greater amounts compared to the power values observed with active recovery methods. The study concludes that the use of active recovery during short durations of high intensity exercise may increase power output far greater compared to methods of passive recovery (Connolly, Brennan, Lauzon, 2003). This research relates to the present study by demonstrating how active recovery promotes increased performance compared to passive methods of rest during physical activity.

Methods of muscle recovery are very important aspects of interest to physical fitness professionals, due to the fact that many athletic events involved repeated performances with only a short duration of rest between each set (Mika, Mika, Fernhall, Unnithan, 2007). There is a current need in the field of physical education to develop the best possible means of enhancing the rate of recovery for an athlete after fatigue during physical activity (Mika, et al. 2007). The purpose of this study was to evaluate the impact of postisometric relaxation, active recovery, and passive recovery on muscle recovery after dynamic exercise (Mika, et al. 2007). The study consisted of ten healthy recreationally active men with age ranges from 24 to 38 years. The experimental protocols of the study included five laboratory visits by which each was separated by 1 week to avoid the effects of muscle fatigue on the recorded measurements for each session (Mika, et al. 2007). Each session involved the participant warming up for a period of 3 minutes before performing 3 sets of dynamic leg extension and flexion at 50% of a maximal voluntary contraction. Each bout allowed for 30 seconds of rest in between each set by which one of the subscribed relaxation protocols (postisometric relaxation, active recovery, and passive recovery) would be utilized during the period (Mika, et al. 2007). Postisometric relaxation consisted of stretching the exercised muscle groups to the point of onset resistance, by which the participant would slightly contract with the assistance of a facilitator for about 5 seconds. Once the participant relaxed and inhaled and exhaled completely for one deep breath, the facilitator would stretch the participant further (Mika, et al. 2007). The active recovery method included light pedaling on a cycle ergometer at 60 rpm for five minutes, while the participant lied in a relaxed position for 5 minutes for passive recovery (Mika, et al. 2007).

The results from the study displayed significant increases in average maximal voluntary contraction after active recovery, compared to when the participants engaged in passive or stretching methods. The researchers also found that there was a significant increase in motor unit activation when the subjects used active recovery methods. The findings from the study indicate that the most efficient recovery method after dynamic muscle fatigue involves light physical activity compared to other protocols. This research is important to the present study because it further supports the importance of active recovery during physical activity.

There have been many studies that have analyzed the effects of active recovery as an effective approach to reducing blood lactate in the blood, however, there is still much work to be done in discovering its effect on performance (Corder, Potteiger, Nau, Figoni, Hershberger, 2000). The purpose of this study was to determine how different forms of interset recovery methods effected blood lactate, rate of perceived exertion, and performance during a session of resistance training (Corder, et al. 2000). The participants of the study consisted of fifteen resistance trained males whom were required to have been involved in resistance training for at least 3 days per week for a minimum of six months prior to the beginning the experimentation. The study design included 5 test sessions, by which the first session involved the collection of physical data including onset of blood lactate accumulation (OBLA) and VO2max levels via a maximal test using a cycle ergometer. The second session was utilized for the discovery of each participant's 10RM (10-repetition maximum) for barbell squats, while sessions 3-5 involved the examination of the influence of active and passive recovery on the dependent variables of the study (Corder, et al. 2000). Prior to each resistance training session, each participant laid supine for 10 minutes before the first blood sample was taken to measure the initial levels of blood lactate. Each subject than performed 2 warm-up set of 10 repetitions at 50% of their 10RM. After the 2 warm-up sets were completed, the subjects completed 6 sets of 10 repetitions at 85% of their 10RM for barbell squat, and were randomly assigned to either passive recovery, active recovery at 25% OBLA, or active recovery at 50% OBLA (Corder, et al. 2000). Following the final recovery set, each participant was instructed to perform a maximal amount of repetitions to failure at 65% of their 10RM. The results of the testing displayed lower levels of blood lactate and rate of perceived exertion in active recovery at 25% OBLA compared to passive and 50% OBLA methods. The total repetitions until exhaustion following the final recovery period was significantly higher for 25% OBLA at 29.3 ± 1.8 repetitions, whereas passive was at 24.1 ± 1.8, and 50% OBLA at 23.1 ± 1.7 repetitions (Corder, et al. 2000). From the results, the researchers concluded that an active recovery at 25% OBLA was proven to be the most efficient way of reducing blood lactate and increasing performance during resistance training. This is important to the present study because it demonstrates the effectiveness of active recovery as it increases performance during high intensity resistance training.

With the majority of this literature review's emphasis on active recovery, it is also necessary to focus on the related physiological components that are impacted by aerobic activity during resistance training. Hakkinen's research focuses on neuromuscular fatigue during resistance training with male and female athletes. Heavy resistance strength training causes changes in maximal voluntary neural activation of the exercised muscle groups, leading to decreases in maximal force and strength output (Hakkinen, 1993). The purpose of the study was to discover the effects of heavy resistance training on acute neuromuscular fatigue and short-term recovery in athletes (Hakkinen, 1993). The subjects for the study included ten male and nine female strength athletes, ranging from power lifters, weightlifters, and bodybuilders. The design of the study consisted of neuromuscular performance measurements being taken before the weight training session, six times during, and immediately after the end of the workout (Hakkinen, 1993). Maximal force measurements were also recorded during the recovery period after resting for 1 and 2 hours in addition to 1 and 2 days of rest (Hakkinen, 1993). The strength training protocol included barbell squats beginning with a light load warm-up prior to the maximum performance sets. During the following sets, each participant performed 1RM (repetition maximum) for 20 sets. The athletes were given three minute of recovery between each maximal lift (Hakkinen, 1993). During the testing, the researchers measured neural activation via electromyography, and maximal isometric force and force-time and relaxation-time measurements before and immediately after each resistance training session (Hakkinen, 1993). The results of the study revealed decreased maximal forces in both males and females over the course of the exercise sessions, and significant decreases in maximal neural activation. Hakkinen concluded that heavy resistance training exercise results in significant neural fatigue that leads to decreased force and neural activation capability. This research is pertinent to the current study because active recovery and muscle temperature may have a positive impact on neuromuscular fatigue, leading to increased athletic performance.

For years, including a proper warm-up has been an important aspect of injury prevention in any shape or form of physical activity. Safran, Garrett Jr., Seaber, Glisson, and Ribbeck's research aims to provide support for the importance of warming up before physical activity as an effective means of injury prevention. The purpose of this study was to determine the effects of muscle activation without stretch on the behavior of muscle tendon units (Safran, et al. 1988). The subjects of the study consisted of 10 New Zealand white rabbits, by which three muscles from each hind leg were tested. Each of the rabbits' were tested for force, change of length required to tear muscle fiber, site of failure, and length tension deformation of the tibialis anteriors, extensor digitorum longues, and flexor digitorum longus muscle groups (Safran, et al. 1988). The subjects were kept immobilized while incisions were made to expose each of the muscle fibers for experimentation. The motor nerve of each muscle was stimulated using a Grass S44 stimulator that used to determined the amount of voltage necessary to produce measurable tension within the muscle group (Safran, et al. 1988). The voltage stimulation was defined as simulating isometric predonditioning warm-up methods, by which the researchers could attest the maximal forces to muscular failure within the tested muscle fibers. The results of the study revealed that the isometrically preconditioned muscle groups required increased forces to fail, and were able to be stretched to greater lengths from rest before muscular failure (Safran, et al. 1988). The researchers concluded that increased muscular temperature via isometric precondition may be beneficial in injury prevention by increasing elasticity and length to failure within the muscle fibers (Safran, et al. 1988). These findings are pertinent to the current study because it defines the importance of proper warm-up as a mean of injury prevention during physical activity.

Due to recent studies, temperature is becoming well known as a significant determinant of skeletal muscle function, for heating has been found to create changes force-velocity and maximal power output relationships (Bell, Ferguson, 2009). The purpose of this study was to determine if an increase in temperature affected mechanical efficiency during exercise in women (Bell, Ferguson, 2009). The study included 8 young women aged approximately 24 ± 3 years, and 8 older women aged 70 ± 4 years. The experimental deign consisted of each participant completing a series of cycling exercises in random order under controlled temperature conditions (Bell, Ferguson, 2009). Each control exercise was performed during a single session with approximately 1 hour rest between each set, whereas the heated trial was performed during 2 separate sessions with 1 hour recovery periods (Bell, Ferguson, 2009). The physical activity protocol included a 6 minute session on a cycle ergometer at a power out determined by 75% of the participants' ventilator threshold calculated during pre-experimental submaximal exercise testing (Bell, Ferguson, 2009). Each participant pedaled at frequencies of 45, 60, 75, and 90 RPM under both control and elevated temperature conditions. During testing, the researchers measure mechanical efficiency via pulmonary O2 uptake and overall power output during exercise (Bell, Ferguson, 2009). The results of the study revealed that elevated muscle temperature increased mechanical efficiency in younger women, but decreased overall efficiency in older women subjects. The results reveal that there are differences in age due to sarcopenia and fiber-type alterations with age; however the researcher can also conclude that increased muscle temperate has a positive effect on mechanical muscular efficiency in young females. This study is important to the current study because it establishes increased muscle temperatures as an effective means of assisting with physical performance.

Recent studies have suggested that temperature can be a determining factor of contractility and metabolic properties in muscle tissue (Gray, DeVito, Nimmo, Farina, Ferguson, 2005). The purpose of this study was to discover if elevations in temperature would alter ATP turnover and muscle fiber conduction velocity during maximal power output on a cycle ergometer (Gray, et al. 2005). The subjects consisted of 8 healthy habitually active males with average age of 25 years. The experiment included 2 sessions of maximal sprinting for 6 seconds under normal and elevated temperature conditions, by which was controlled through hot water immersion and electrical blankets (Gray, et al. 2005). ATP turnover was calculated from the analyses of muscle biopsies that were conducted before and after each exercise session, while the muscular conduction velocity was recorded through electromyography analysis. The normal temperature conditions were set to 34.2 degrees celsius, while the elevated temperature rose to 37.5 degrees celsius for the two conditions (Gray, et al. 2005). The result revealed that the rate for ATP turnover for phosphocreatine utilization, glycolysis, and total anaerobic power was was greater in elevated temperature conditions compared to control group (Gray, et al. 2005). From the findings, the researchers concluded that elevated temperatures may be responsible for increased power output by elevating ATP turnover rates and muscular conduction velocity, leading to increased athletic performance. This research is important to the present study because it displays the positive effects of elevated muscle temperature on speed and efficiency of muscle contraction.

Researchers from the same department of the previous study conducted a similar experiment 5 years later focusing on the thermal effects on skeletal muscle tensile behavior (Noonan, Best, Seaber, Garrett, Jr, 1993). The purpose of the study was to investigate the effects of temperature on the failure of muscle tissue mechanics to lead to a better understanding of temperature's role in performance and injury prevention (Noonan, et al. 1993). Similar to the previous study, the researchers used thirty New Zealand white rabbits, in addition to testing similar muscle groups including the tibialis anterior, and extensor digitorum longus (Noonan, et al. 1993). The researchers utilized saline irrigation to control the temperature within the muscle fibers of each rabbit. Each distal tendon of musculotendinous unit was severed from its insertion point and clamped to a servohydraulic testing machine (Noonan, et al. 1993). To simulate muscle activation, a small electrical current was passed through a S44 Grass stimulator of a small voltage of .5 volts. The animal subjects were separated into three groups including muscle pulling to failure at passive failure for 10 cm/sec, passive failure at 1 cm/sec, and active failure for 10 cm/sec. The findings of the study revealed resistance loads to failure were higher at colder temperatures for all groups tested. Energy absorption and stiffness were also significantly higher in cold muscles compared to muscular fibers exposed to elevated temperatures (Noonan, et al. 1993). These results reveal that thermal effects have a significant impact on muscle tensile behavior, by which lower temperatures put muscle fibers at risk for increased tear and injury potential. The researchers concluded that the findings of the study support their hypothesis that warmer muscular temperatures can help prevent injury and improve performance in physical activity (Noonan, et al. 1993).

The following research is important to the current study because it demonstrates the positive impact of elevated muscle temperatures on injury prevention and overall performance. From the research we can conclude that active recovery can be used as an efficient tool during resistance training due to its implied positive effects on strength, power output, mechanical performance, hormonal response, metabolic output, and neuromuscular recovery which may warrant the need for further study.

Chapter III - Methods and Procedures

The research study will consist of a 72-hour data collection period to assess the effects of active recovery on lactate clearance and energy expenditure. The study will be performed utilizing male and female collegiate athletes. The first day will consist of pre-screening protocols, an instructional information session, body composition measurement, and accelerometer distribution. The 2nd day will include the facilitation of the resistance training protocol and secondary instruction session. The 3rd day will consist of the final meeting with the participant, explanation of the data/results, and return of the accelerometer.

Participants

The study will include 50 active collegiate athletes who are currently participating in a varsity sport and strength & conditioning program. Participants were recruited from University's varsity athletic population between the ages of 18-26 years old. After indicating interest in participation, participants completed a standardized PAR-Q questionnaire utilized by the Exercise & Sports Science Department at Eastern Kentucky University to assure clearance for physical activity.The participants will also be screened for inclusion using a Health/Blood Questionnaire for clearance for the finger prick blood analysis procedure during the weight training portion of data collection. Participants will be excluded from participation if they do not meet the age requirements for the study and/or if they answer "Yes" to any of the questions in the PAR-Q Questionnaire and do not provide physical activity clearance from a certified athletic trainer/team doctor.

Participants will be immediately excluded if they answer "Yes" to any of the questions listed in the Health/Blood Questionnaire for Finger Prick Blood Analysis.

Instruments/Apparatus

In order to assess body composition, the researchers utilized an official BOD Pod system. The BOD Pod is a gold standard measurement of body composition using air displacement plethysmography, making it ideal for research applications. The researchers also utilized the TANITA BIA scale to offer a second measure of body composition.

Particular apparatus' used for the study included standard weight lifting equipment utilized during the resistance training session. A standard Monark-Model 864 Cycle Ergometer will be utilized for the interset rest period of active recovery during the resistance training session. The participant performed various lifts using standard Olympic bench presses, squat racks, and mobile benches. In addition, the participants also used standard Olympic barbells and kettlebells.

Each participant will be tested for blood lactate levels utilizing a Nova Biomedical Lactate Plus Lactate Meter. The lactate meter is a common tool utilized in various cliinical and medical settings, making it ideal for this research study.

In order to justify how active recovery during high intensity resistance training impacts total energy expenditure and levels of activity outside athletics, it is necessary to utilize Body Media Fit Accelerometers. Body Media armbands are clinically tested accelerometers that rival doubly-labeled water as an acceptable means of measuring energy expenditure, making it ideal for use in this research investigation.

Reliability/Validity of Instruments

The BOD Pod is a gold standard measure of method giving an R value of .93 accuracy rating for body composition analysis (McCrory, Gomez, Bernauer, 1995). The BOD Pod apparatus is completely controlled via computer software with minimal human interaction, making the BOD Pod a suitable means of measurement for the research study.

The BORG scale itself is an effective means of measuring rates of perceived exertion, with a reliability value of .80, and a validity coefficient of .90 (Chen, Fan, Moe, 2002). However, the BORG scale for measuring RPE is a tool which is limited by the trustworthiness of the participant. In order to ensure reliable measurements of perceived exertion, it will be necessary to properly instruct each of the participants the meaning of each level of exertion and how to properly identify, and covey it to the researcher.

The Monark cycle ergometer is a standard aerobic apparatus utilized in many research, clinical, and practical applications for physical activity, and maximal effort testing, making it a reliable tool for this study. The Olympic weight lifting equipment is standard to resistance training programs and routines making them highly reliable for usage in the research study. All Cybex equipment was subjected to proper maintenance prior to the beginning of the study to prevent mechanical issues during workout sessions.

Fruin, Rankin, 2004., conducted a study to validate the efficiency of Body Media Fit Accelerometers against the gold standards of energy expenditure measurement, doubly labeled water and indirect calorimetry during resting and exercise conditions. The researchers found that armbands provided valid and reliable estimates of total energy expenditure in young, normal weight adults (Fruin, Rankin 2004). A second study tested the ability of the armbands to assess the daily energy expenditure in older aged populations. The researchers findings revealed that the measurements from both doubly labeled water and the accelerometers were highly correlated, revealing the armbands to be reliable means of measuring energy expenditure (Mackey, et.al 2011).

Preliminary Procedures

The first meeting with the participant occurred at the Exercise Physiology Lab in Moberly room 223 during the first 24 hours of the 3-day period. All participants were informed of the purpose of the study, and any known risks that may be associated with physical activity. All participants were informed of their right to withdraw at any point during the course of the study. Each participant was required to sign a statement of informed consent, in addition, each athlete will subjected to a medial questionnaire known as the "PAR-Q" to assess if a participant was cleared for vigorous physical activity. The athlete will also complete a Blood Health Questionnaire for Finger Prick Blood Analysis. Any subject that displayed medical problems or concerns will be unable to participate within the research study. Once all required forms are signed and documented, the participant were randomly assigned to the experimental or control group.

Athropometric data including height & weight was collected, in addition to resting blood pressure values utilizing a standard blood pressure cuff and sphygmomanometer. Each athlete was also tested for body composition using an official BOD Pod system and TANITA BIA scale. In order to receive an accurate measurement, the participants will be instructed to not consume a meal or drink any beverage at least 2 hours prior to arriving for preliminary testing.

On completetion of the anthropometric tests, the participant will be informed of the protocol for usage of the Body Fit Media Accelerometer. Before distribution of the accelerometer, the participant will be instructed to carry out their normal daily activities, but must refrain from organized physical activity (recreational fitness, strength & conditioning workout, etc.) on the 1st and 3rd day of the study. The participants will be allowed to consume a normal diet, however, they will be asked to refrain from usage of alcohol to prevent decline in performance during the resistance training testing session. Each participant must wear the accelerometer the entire duration of the study (72 hours), including the resistance training session on Day 2. The accelerometer will be worn by each participant around their upper arm, and will only be allowed to be removed for bathing purposes. The accelerometer must be worn at all times and must not be removed until the end of the 72 hour period at the final meeting on the 3rd day. The accelerometer will be measuring total energy expenditure(calories), physical activity intensity (vigorous, moderate, light), and sleep efficiency. The data will be collected from the accelerometer upon its return on the 3rd day via Body Media Computer software. All of these initial protocols will be identical for both the control and experimental groups.

Experimental Procedures

The second stage of the research will continue on the 2nd day with the resistance training session facilitation. The participants will be instructed to arrive on time to their scheduled session at the Jack Ison Varsity Weight Room in Moberly Building. All measurements during the study were recorded using standard data tables using paper and pencil materials.

The resistance training session was conducted by professional collegiate certified strength & conditioning coaches. The testing includes a high intensity resistance training session which will determine the effect of the inclusion or absence of active recovery during the resting periods of the training session. The resistance training protocol consists of 5 exercise circuits known as power clusters. Power clusters consist of performing 70% of an athletes 1RM on each specified exercise. The 70% of 1RM on exercises will be determined by the records of the strength & conditioning coaches of the university. The athlete performs 2 reps with a 15 second break 4 times for a total of 8 reps, followed by a 3 minute rest period before the power cluster of the specificed exercise is performed for a 2nd time. After the 2nd set of the specified exercise, the athlete will receive a 3 minute rest period before moving on to the next power cluster. The specified exercise are as follows: Power Cleans, Barbell Squats, Barbell Bench Press, Barbell Bent-Over Row, and Kettle Bell Swings.

During each 3 minute rest period, each participant was tested for blood lactate levels utilizing Corder, K. P., Potteiger, J. A., Nau, K. L., Figoni, S. F., & Hershberger, S. L. (2000)'s approved method for finger prick blood lactate analysis using a Nova Biomedical Lactate Plus Lactate Meter. Finger prick blood analysis was done in a safe area of the varsity weight room, away from all equipment used by athletes to prevent person-to-person exposure to blood samples. Each blood sample and materials used to clean athletes fingers was exposed of using Bio-Safe containers used by the university's certified athletic training room.

After the finger prick blood analysis is complete, the participants in the experimental group will perform the active recovery protocol by cycling at 75 RPM at minimum resistance on a basic cycle ergometer the remaining 2 minutes of the 3 minute rest period. After the finger prick analysis, the control group remained seated until the start of the next power cluster/exercise. Finger prick analysis will occur at rest before the start of the session, at the end of each 2nd set of each power cluster, and 5 minutes after the final exercise cluster for a total of 7 finger prick blood tests per participant. The final analyzed variable during the resistance training session was rate of perceived exertion using the Borg scale. The participant will be shown the BORG scale on a chart at the start of the training session, before the beginning of each power cluster, after the 1st set, and after the 2nd set of each cluster. Before releasing the athlete at the conclusion of the resistance training session, the participant will be instructed to keep the accelerometer on until the final meeting on the next day.

Upon the participants arrival for the final meeting in Moberly 223, the accelerometer was collected, and the data was uploaded to the computer via Body Media software. The participant was then debriefed on the results from the study, upon which the 72 hour testing session was complete.

Chapter IV – Manuscript

Abstract

Purpose: With the development of more intense and complex strength and conditioning programs, it is necessary to discover the best possible means of recovery during workout sessions to increase athletic performance. The objective of this study is to evaluate the effects of active recovery during the rest periods of a resistance training session on lactate clearance in varsity collegiate athletes. **Methods:** Twenty healthy varsity collegiate athletes age 18-22 yr participated in a collegiate strength and conditioning workout session. Participants were randomly divided into an active recovery group (A.R.) and a passive recovery group (P.R.). Both groups performed 5 exercises for 2 sets of 8 repetitions at 70% 1RM, with 3 minutes of recovery between each set. The exercises were performed in the following order: Power Clean, Barbell Squat, Barbell Bench Press, Barbell Bent-Over Row, and Kettlebell swings. A.R. consisted of cycling on a Monark cycle ergometer at minimum resistance at 60 rpm during each 3 minute rest period, while P.R. remained stationary for the duration of the rest period. The blood lactate levels were recorded during each 2nd rest period utilizing finger prick blood analysis via Nova blood lactate analyzers. The changes in blood lactate were compared between A.R. and P.R. groups using a 5 x 2 repeated measures ANOVA statistical analysis. **Results:** The repeated measures ANOVA revealed no significant difference of blood lactate levels between groups overall during the workout session. However, the results yielded a strong trend between groups during the power clean exercise circuit; *p*=.053. **Conclusions:** There were no significant differences between A.R and P.R. groups during the overall resistance training session, but significant differences between

groups during power cleans, revealing that active recovery interventions may be beneficial if performed after more strenuous, full-body resistance training movements.

Introduction

The majority of research on active recovery as an efficient tool during physical activity has revealed positive indications of improving athletic performance and decreasing vulnerability to sustaining injury (Cronin, Mohamad, Nosaka, 2012). Active recovery involves performing light aerobic activity in between sets or repetitions of either high-intensity cardiovascular or resistance training. Aerobic activity is most notable for improving metabolic factors during physical activity such as oxygen uptake, and blood lactate clearance which allow for increased performance during exercise (Cronin, Mohamad, Nosaka, 2012). Studies have shown that active recovery positively impacts athletic performance by increasing muscle temperature, increasing muscular resiliency, improving metabolic and neuro-muscular factors.

Through various studies, researchers can conclude that increases in muscular temperature have been found to be a well known determinant for skeletal muscle function, creating changes in maximum power and performance variables (Bell & Ferguson, 2009). Findings from the research suggest that increased muscular temperature increases muscular mechanical efficiency, allowing individuals to engage in bouts of physical activity more efficiently, and for longer durations (Bell & Ferguson, 2009). A similar study by Gray, Vito, Nimmo, Farina, & Ferguson, (2006) discovered that increased muscular temperature resulted in significantly improved ATP turnover for energy production, blood lactate removal, and total anaerobic power compared to normal temperature levels, leading to considerably improved physical performance. Bogdanis, G., Nevill, M., Lakomy, H., Graham, C., & Louis, G (1996) conducted a study analyzing the effects of active recovery during the interset periods of high intensity sprinting on a cycle ergometer. The findings of the research displayed significantly higher power output in the 2nd set of sprints in the group utilizing active recovery due to increased oxygen uptake levels which were not evident in the group utilizing passive recovery (Bogdanis, et. al, 1996). A similar study also revealed considerable results, revealing power output levels decreasing significantly faster in sprinters whom did not utilize active recovery methods during each resting stage of the workout component of the study (Connolly, Brennan, Lauzon, 2003).

A recent research study analyzed how recovery from muscular fatigue during training may positively impact neuromuscular function, and thus promote athletic performance (Mika, Mika, Fernhall, Unnithan, 2007). Mika et. al analyzed the effects of stretching, active recovery, and passive recovery on muscular recovery after a leg extension exercise. The study's results displayed greater increases in motor unit activations of the quadriceps muscle after using active recovery procedures consisting of light aerobic cycling for 5 minutes between each set (Mika, et. al, 2007). The findings of the research suggest that the implementation of active recovery sessions may not only improve muscular metabolic function, but can also improve performance in avenues of neuromuscular function with increased muscular function (Mika, et.al, 2007).

As fitness professionals, it is necessary to discover the best possible means of recovery during workout sessions to not only increase athletic performance, but the quality of life outside of athletics of collegiate athletes. As a result, the purpose of this study will be to determine the effects of active recovery during high-intensity resistance training on athletic performance and energy expenditure in collegiate athletes.

Methods

The research study will consist of a 72-hour data collection period to assess the effects of active recovery on lactate clearance and energy expenditure. The study will be performed utilizing male and female collegiate athletes. The first day will consist of pre-screening protocols, an instructional information session, body composition measurement, and accelerometer distribution. The 2nd day will include the facilitation of the resistance training protocol and secondary instruction session. The 3rd day will consist of the final meeting with the participant, explanation of the data/results, and return of the accelerometer.

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Results

Statistical Analysis

Demographic data, independent variable, and dependent variables were initially recorded in Excel (Microsoft Corporation, Redmond, WA) and then analyzed using SPSS Statistics 21 (SPSS, Inc., Chicago, IL). Differences in the dependent variables (blood lactate clearance, rate of perceived exertion (RPE), and HR (BPM)) that were elicited by the intervention were analyzed using repeated measures ANOVA. This analysis included three separate 5x2 repeated measures ANOVAs to analyze differences from each variable over time between the two groups (AR & PR). Paired sample t-tests were utilized to examine differences in genders in both groups. An alpha of $p<0.05$ was considered statistically significant for all comparisons.

Initial analyses consisted of group differences in anthropometric data between passive recovery (PR) and active recovery (AR) groups. All values, means, test statistics, and p-values were computed via independent t-tests between the two groups

Gender Differences among Groups

Twenty-three total participants were screened during the preliminary research of the study. Only twenty of the participants were eligible to participate within the experimental procedures. The gender groups consisted of 15 females and 5 males. Each of the participants was required to go through preliminary anthropometric testing. The testing measures included, age, weight, resting heart rate(HR), years of collegiate sports played, Bod Pod body fat percentage, Bod Pod fat-free mass, Tanita body fat percentage, and Tanita fat-free mass. Measures of significant difference between the two genders were total body weight (p=.000), BodPod fat% (p=.001), BodPod free-fat mass (p=.000), Tanita Fat% (p=.000), and Tanita FFM (p=.000). These measures display great significance between the two genders in terms of weight, body fat percentage, and overall Fat-Free Mass revealing that total body weight may carry an impact on total force production. In addition fat-free mass contributing to overall lactate production during anaerobic glycolysis, leading to a greater disparity among the gender among the two recovery groups.

Resistance Training Protocol Measures

The testing session consisted of three performance measures during the resistance training protocol, including blood lactate clearance (mmol), rate of perceived exertion (RPE), and heart rate (BPM).

A 5 x 2 repeated measures analysis of variance over the course of all five resistance training exercises, the study revealed no significant differences between AR and PR groups with an F=1.671, P=.213. This lack of difference indicates that the presence or absence of an aerobic activity intervention during the resistance training protocol did contribute to a difference in fatigue over the course of time.

In addition, the researchers also conducted a 5 x 2 repeated measures ANOVA for effects on heart rate between groups over time of the protocol. The test revealed no significance between the two groups (F=1.699, p=.222), indicating the active recovery intervention carried no significant impact on heart rate during the course of the protocol.

A third 5 x 2 repeated measures ANOVA was utilized to test for significance in blood lactate) mmol over the course of the resistance training protocol between AR and PR groups. The test revealed no significant difference at p = 0.256, indicating that active recovery has no significant impact upon blood lactate clearance in this protocol.

Blood Lactate Clearance Trends

Although there was no overall significance in blood lactate means between the AR and PR groups among the resistance training protocol as a whole, there were some significant trends indicating particular exercises may have shown significance with more efficient program design. The most prominent trend was the power clean exercise, yielding a significance level of p=.053. This may indicate that larger compound multi-joint exercises may be more efficient at creating a proficient lactate response in which an active recovery intervention may help decrease overall blood lactate concentrations.

Discussion

The inclusion of an active recovery intervention during the rest periods of a high intensity resistance training session does not produce a significant difference in blood lactate levels compared to passive recovery. This study showed that blood lactate levels of the collegiate athletes did not significantly differ between groups throughout the five lifts of the resistance training protocol. Although the experimental group displayed trends in lower lactate levels in the larger compound lifts in the experimental group, such as in the Barbell Squat and Power Clean; these trends were not statistically different from the participants utilizing passive recovery.

With the utilization of a high-intensity resistance training protocol, research shows that there is not an ample amount of time for the anaerobic system to recover, thereby increasing metabolic byproducts of glycolysis, such as lactate (Sahlin, 1986). This blood lactate has been found to negatively impact kinetics and kinematics of movement during resistance training movements, resulting in overall decreased strength outputs and performance (Nummela, Vuorimaa, Rusko, 1992). Lactic acid accumulation in skeletal muscle can be cleared with the presence of oxygen by accelerating the oxygenation of lactate to pyruvate which is used as fuel during the Kreb’s cycle or utilized by the liver to create glucose via gluconeogenesis (Cronin et. Al, 2012). However, during high intensity resistance training sessions designed for hypertrophy adaptations, research has shown that this process’s efficiency decreases (Poehlman, Melby, 1998). Therefore, the inclusion of active recovery during a high intensity resistance training may enhance lactate clearance, and overall contribute to an increase in performance.

Due to our assumptions, the experimental group was expected to have lower blood lactate levels during each of the lactate tests over the course of time throughout the resistance training session. However, the resistance training protocol produced no significant changes between active and passive recovery groups.

In addition to the contributions of the program design, the research was also limited to the low number of participants used in the study. The inclusion of a greater number of athletes would have increased the variability and may have encouraged the seen trends of lower blood lactate levels overtime between the exercises into becoming significant values. Furthermore, the study's population of athletes may have also contributed to research design flaw due to their increased training status compared to normal individuals. Collegiate athletes consistently participate in vigorous strength & conditioning programs that promote overall improved cardiovascular conditioning and resiliency to fatigue during strength training compared to non-athlete individuals. The athletes' increased training status may have nearly nullified the effects of active recovery, due to the fact that their physiological energy systems are efficiently adapted to higher intensities of physical activity.

Flaws in the resistance training protocol design may have contributed to the lack of increased lactate response among the participants of the study. Normal hypertrophy designed resistance training programs consist of using a 70-85% 1 RM for at least eight to twelve repetitions for one to four sets (Poliquin, 1990). The designed resistance training protocol was comprised of five exercise denoted as power clusters, where two reps were completed every fifteen seconds for a total of eight reps followed by a three minute recovery period for the inclusion or absence of light aerobic cycling. The inclusion of the fifteen second rest period between performing a lift of a 70%1RM for two repetitions may not be of high enough intensity to elicit a sufficient anaerobic response to generate enough lactic acid for active recovery to produce an increased clearance effect. Further research could avoid this issue by designing protocols consisting of higher sets and volume in order to elicit a proper anaerobic response leading to greater production of metabolic byproducts, such as lactic acid.

The gender differences in the research negatively impacted the results of the study due to the uneven numbers of females versus male participants. The differences in strength in relation to males and females may correlate to the effectiveness of active recovery in relation to power output and differences in blood lactate responses. One study researched strength differences where women were approximately 52% and 66% as strong as the men in the upper and lower body musculature respectively (Miller, MacDougall, Tarnopolsky, Sale, 1993). The men were also stronger relative to lean body mass. A significant correlation was found between strength and muscle cross-sectional area , where women had 45, 41, 30 and 25% smaller muscle cross sectional areas for the biceps brachii, elbow flexors, vastus lateralis and quadriceps muscles respectively (Miller et. al, 1993). The data collected suggests that the greater strength of the men was due primarily to larger type I and type II muscle fibers. The greater gender difference in upper body strength can probably be attributed to the fact that women tend to have a lower proportion of their lean tissue distributed in the upper body, indicating men possessing the ability to outperform women in upper body exercises (Miller et. al, 1993). The findings from Miller et. al (1993)'s study may imply that the exercises chosen to be performed by the athletes in the resistance training protocol may not have elicited significant blood lactate responses, due to the gender differences in lean muscle tissue and overall strength in males versus females. These implications should be used to advise future researchers to narrow participants to a specific gender classification to remove the possibility of gender differences interfering with the results of the research.

Conclusion

These results indicate that active recovery does not have a significant impact on blood lactate clearance during high intensity resistance training. Although the active recovery group displayed trends in overall lower blood lactate levels compared to the passive recovery group in both the power clean and barbell squat exercises, blood lactate clearance across all stages of resistance training protocol did not display significance between the two groups. This lack of significance between groups may have been attributed to athlete training status, flaws in resistance training protocol design, and overall differences. Future testing should examine active recovery interventions with a training protocol designed more for maximizing hypertrophic adaptation with a higher volume of sets and repetitions with the prescribed exercises. In addition, future researchers should test non-athlete populations to better assess the efficacy of active recovery interventions in individuals possessing lesser adapted physiological energy systems.

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Appendix A – Informed Consent Document

Consent to Participate in a Research Study

The Effects of Active Recovery during High Intensity Resistance Training on Lactate Clearance and Energy Expenditure in Collegiate Athletes

Why am I being asked to participate in this research?

You are being invited to take part in a research study about the effects of active recovery during the rest periods of high intensity resistance training. You are being invited to participate in this research study because you are a collegiate athlete that will give us a great insight as to how different recovery methods increase overall athletic performance and well-being. If you take part in this study, you will be one of about 50 people to do so. We are looking into this study to determine if the presence of active recovery will increase rates of lactate clearance during physical activity, as well as increase your total energy expenditure after the completion the high-intensity resistance training session. If active recovery does have an effect on an athlete's ability to increase performance, it will allow us to link this to training performance to become a viable training element of strength & conditioning programs.

Who is doing the study?

The person in charge of this study is Christopher Perry, a graduate student at Eastern Kentucky University. He is being guided in this research by his faculty advisor, Dr. Peter Chomentowski.

What is the purpose of the study?

By doing this study, we hope to learn if active recovery will have an effect on lactate clearance and overall energy expenditure.

Where is the study going to take place and how long will it last?

The research procedures will be conducted at Moberly Building, Eastern Kentucky University. You will need to come 3 times during the study. Each of those visits will take about 30 minutes to 1 hour. The total amount of time you will be asked to volunteer for this study is 72 hours over the next 3 days.

What will I be asked to do?

When you arrive, The first meeting will occur at the Exercise Physiology Lab in Moberly room 223. You will be required to sign this statement of informed consent, in addition, each you will complete a medical questionnaire known as the "PAR-Q" to assess if you are cleared for vigorous physical activity. You will also complete a Blood Health Questionnaire for Finger Prick Blood Analysis. If you display any medical problems or concerns, you will be unable to participate within the research study.

Once all required forms are signed and documented, you will be assigned to the experimental or control group. Athropometric data including height & weight will be then be measured, in addition to blood pressure utilizing a standard blood pressure cuff and sphygmomanometer. You will then have your body composition measured using an official BOD Pod system. In order to receive an accurate measurement, please do not consume a meal at least 2 hours prior to arriving for preliminary testing.

You will then be instructed on how to use the Body Fit Media Accelerometer. During testing you will be instructed to carry out your normal daily activities, but must refrain from organized physical activity (recreational fitness, strength & conditioning workout, etc.) on the 1st and 3rd day of the study. You will be allowed to consume a normal diet, however, please refrain from usage of alcohol to prevent decline in performance during the resistance training testing session on the 2nd day. You must wear the accelerometer the entire duration of the study (72 hours), including the resistance training session on Day 2. The accelerometer will be worn around the upper arm, and will only be allowed to be removed for bathing purposes. The accelerometer must be worn at all times and must not be removed until the end of the 72 hour period at the final meeting on the 3rd day. The accelerometer will be measuring total energy expenditure(calories), physical activity intensity (vigorous, moderate, light), and sleep efficiency. The data will be collected from the accelerometer upon its return on the 3rd day via Body Media Computer software.

The second stage of the research will continue on the 2nd day with the resistance training session facilitation. You must arrive on time to the scheduled session at the Jack Ison Varsity Weight Room in Moberly Building. The resistance training session will be conducted by professional collegiate certified strength & conditioning coaches. The testing will include a high intensity resistance training session which will determine the effect of the inclusion or absence of active recovery during the resting periods of the training session. The resistance training protocol consists of 5 exercise circuits known as power clusters. Power clusters consist of performing 70% of an athletes 1RM on each specified exercise. The 70% of 1RM on exercises will be determined by the records of the strength & conditioning coaches of the university. The athlete will perform 2 reps with a 15 second break 4 times for a total of 8 reps, followed by a 3 minute rest period before the power cluster of the specificed exercise is performed for a 2nd time. After the 2nd set of the specified exercise, the athlete will receive a 3 minute rest period before moving on to the next power cluster. The specified exercise are as follows: Power Cleans, Barbell Squats, Barbell Bench Press, Barbell Bent-Over Row, and Kettle Bell Swings.

During each 3 minute rest period, you will be tested for blood lactate levels utilizing an approved method for finger prick blood lactate analysis. Finger prick blood analysis will be done in a safe area of the varsity weight room. After the finger prick blood analysis is complete, if you are in the experimental group you will perform the active recovery protocol by cycling at 75 RPM at minimum resistance on a basic cycle ergometer the remaining 2 minutes of the 3 minute rest period.

After the finger prick analysis, if you are assigned to the control group, you will remain seated until the start of the next power cluster/exercise. Finger prick analysis will occur at rest before the start of the session, at the end of each 2nd set of each power cluster, and 5 minutes after the final exercise cluster for a total of 7 finger prick blood tests per participant.

The final analyzed variable during the resistance training session will be the rate of perceived exertion using the Borg scale. You will shown the BORG scale on a chart at the start of the training session, before the beginning of each power cluster, after the 1st set, and after the 2nd set of each cluster. Before releasing the athlete at the conclusion of the resistance training session, the participant will be instructed to keep the accelerometer on until the final meeting on the next day.

Upon your arrival for the final meeting in Moberly 223, you will complete an energy fatigue survey to assess how you felt after the completion of Day 2's training session. The accelerometer will then be collected, and the data will be uploaded to the computer via Body Media software. You will then be debriefed on the results from the study, and the 72 hour testing session will be complete.

Are there reasons why I should not take part in this study?

You may be excluded from this if you do not meet the inclusion criteria. The researchers will discern if you do not qualify. You may find it difficult to partake in this study if you are a smoker, or may be pregnant, due to the extent of the resistance training session. All other predetermined factors will be taken into account that may exclude you from this study.

What are the possible risks and discomforts?

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life as a collegiate athlete involved in a collegiate strength & conditioning program.

You must be aware that by participating in this study, you may experience muscle soreness that could persist up to a few days following testing. This is a natural process for the body and common result from vigorous physical activity.

You may, however, experience a previously unknown risk or side effect.

Will I benefit from taking part in this study?

Benefits from the study include knowledge of your personal overall daily energy expenditure, and body composition measurement. In addition, you will discover your physical capabilities through your performance in the resistance training session.

Do I have to take part in this study?

If you decide to take part in the study, it should be because you really want to volunteer. Your coach does not require that you participate in the study. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

If I don't take part in this study, are there other choices?

If you do not want to be in the study, there are no other choices except to not take part in the study.

What will it cost me to participate?

There are no costs associated with taking part in this study.

Will I receive any payment or rewards for taking part in the study?

You will not receive any payment or reward for taking part in this study.

Who will see the information I give?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about this combined information. You will not be identified in these written materials.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from the information you give, and these two things will be stored in different places under lock and key.

Can my taking part in the study end early?

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to participate. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to end your participation in the study. They may do this if you are not able to follow the directions they give you, if they find that your being in the study is more risk than benefit to you, or if the agency funding the study decides to stop the study early for a variety of scientific reasons.

What happens if I get hurt or sick during the study?

If you believe you are hurt or if you get sick because of something that is done during the study, you should call Christopher Perry at (443)-683-3159 immediately. It is important for you to understand that Eastern Kentucky University will not pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. That cost will be your responsibility. Also, Eastern Kentucky University will not pay for any wages you may lose if you are harmed by this study.

Usually, medical costs that result from research-related harm cannot be included as regular medical costs. You should ask your insurer if you have any questions about your insurer's willingness to pay under these circumstances.

What if I have questions?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Christopher Perry at (443)-683-3159. If you have any questions about your rights as a research volunteer, contact the staff in the Division of Sponsored Programs at Eastern Kentucky University at 859-622-3636. We will give you a copy of this consent form to take with you.

What else do I need to know?

You will be told if any new information is learned which may affect your condition or influence your willingness to continue taking part in this study.

I have thoroughly read this document, understand its contents, have been given an opportunity to have my questions answered, and agree to participate in this research project.

____ ____________________

Signature of person agreeing to take part in the study Date

____

Printed name of person taking part in the study

____

Name of person providing information to subject

Appendix B – Recruitment Script of Athletes

Recruitment Script/Cover Letter to Coaches of Athletes:

"We will be conducting a study relating to the effects of active recovery during the rest periods of high intensity resistance training. Here is some background on the related research conducted in the past.

The majority of research on active recovery as an efficient tool during physical activity has revealed positive indications of improving athletic performance and decreasing vulnerability to sustaining injury. This thesis research project will attempt to analyze the effects of active recovery during high-intensity resistance training on athletic performance variables in collegiate female athletes (Softball and Volleyball athletes). Studies have shown that active recovery positively impacts athletic performance by increasing muscle temperature, increasing muscular resiliency, improving metabolic and neuro-muscular factors.

Active recovery involves performing light aerobic activity in between sets or repetitions of either high-intensity cardiovascular or resistance training. Aerobic activity is most notable for improving metabolic factors during physical activity such as oxygen uptake, and blood lactate clearance which allow for increased performance during exercise (Cronin, Mohamad, Nosaka, 2012). Though the research suggests that active recovery is indisputably one of the best tools for improving performance during shorts bouts of resistance training, it is still unclear as to the benefits to realistic strength & conditioning sessions. In addition, researchers are uncertain of active recovery's impact upon an athlete's level of activity during a normal daily routine and their total energy expenditure. Popular trends indicate that more athletic teams are taking part in high-resistance training protocols, consisting of explosive movements, full-body muscular utilization, and performing repetitions to muscular failure; all such condition factors of training that lead athletes to feelings of fatigue in their normal activities outside of athletics.

In order to justify how active recovery during high intensity resistance training impacts total energy expenditure and levels of activity outside athletics, it is necessary to utilize Body Media Fit Accelerometers. As fitness professionals, it is necessary to discover the best possible means of recovery during workout sessions to not only increase athletic performance, but the quality of life outside of athletics of collegiate athletes. As a result, the purpose of this study will be to determine the effects of active recovery during high-intensity resistance training on lactate clearance and energy expenditure in collegiate female athletes.

For the purpose of the study, it will be necessary to utilize athletes as subjects who utilize high intensity strength training protocols. With your assistance in allowing your athletes to be apart of the this study, not only will you contribute to the research in exercise science, but the possible findings of a viable element to be included in strength & conditioning programs to increase athletic performance. The participation of your athletes is completely voluntary. If you have any questions regarding the study, please contact me at (443)-683-3159, or you can reach me at my EKU email, christopher_perry42@mymail.eku.edu. Thank you."

Appendix C – Project Alert Data Sheet

Exercise Science Research Laboratory
Eastern Kentucky University
PROJECT ALERT DATA SHEET

Day 1 – Initial Screening Data:

ID#:	Height:	Weight:
Date:		
	Age:	DOB:
	Recovery Mode:	Years Played:

Body Composition/Resting Measurements			
	Body Fat-	FFM-	RMR-
BOD POD ANALYSIS:			
TANITA ANALYSIS:			
Resting Blood Pressure:			
Resting Heart Rate:			

Arm Band Screening Data (Time & Date)	Armband ID#-
Start Time:	
End Time:	

Day 2 - Resistance Training Protocol Data:
DATE:

Start Time -

End Time –

Recovery Mode-

Preliminary Measurements –

Resting Heart Rate (BPM)	
Resting Blood Pressure (SP/DSP)	
Resting Blood Lactate (mmol)	

During Testing Measurements –

Power Cluster	Blood Lactate (mmol)	RPE 1/2/3	HR Before/During/After
1. Clean Circuit			
2. Squat Circuit			
3. Bench Circuit			
4. Bent-Over Row Circuit			
5. Kettle Bell Swing Cir.			

After Testing Measurements –

Post Lactate Test (5 minutes) –

Day 3 – Energy Expenditure Calculations

Armband ID#: 1st – 24 Hours (Time/Date):

Time/Date Armband Started: 2nd – 24 Hours (Time/Date):

Time/Date Armband Ended: 3rd – 24 Hours (Time/Date):

	1st - 24 Hours	2nd - 24 Hours	3rd - 24 Hours
Calories Burned			
Steps Taken			
Moderate Activity			
Vigorous Activity			
Sedentary Activity			

	Totals (72 Hour Period)
Calories Burned	
Steps Taken	
Moderate Activity	
Vigorous Activity	
Sedentary Activity	

Appendix D – Energy Survey

ID# -
Date-

These questions are about how you felt from the completion of the training session to when you went to bed, and how you feel from when you wake up to when you arrive for the final meeting on Day 3 of testing.

Circle the correct answer about how you felt for the duration of the day of training, and the day following.

	Not at all	A little of the day	About half the day	Most of the day	All day
Did you feel exhausted out today?	0	1	2	3	4
Did you have a lot of energy?	4	3	2	1	0
Did you feel tired?	0	1	2	3	4
Did you have enough energy to do the things you wanted to do?	4	3	2	1	0
Did you feel full of pep?	4	3	2	1	0

Sum of answers: ______________________

Appendix E – BORG SCALE: Rate of Perceived Exertion

BORG SCALE – RATE OF PERCEIVED EXERTION

6 No exertion at all

7

Extremely light (7.5)

8

9 Very light

10

11 Light

12

13 Somewhat hard

14

15 Hard (heavy)

16

17 Very hard

18

19 Extremely hard

20 Maximal exertion

Appendix F – PAR-Q Questionnaire

PAR-Q & YOU

Physical Activity Readiness Questionnaire

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age and not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly.

YES NO 1. Has you doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

YES NO 2. Do you feel pain in your chest when you do physical activity?

YES NO 3. In the past month, have you had chest pain when you were not doing physical activity?

YES NO 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

YES NO 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

YES NO 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

YES NO 7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions, talk with your doctor before you start becoming much more physically active.

If you answered NO to all questions, you can be reasonably sure that you can:

- Start becoming much more physically active—begin slowly and build up gradually.
- Take part in a fitness appraisal—this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME____ DATE________________________________

SIGNATURE_____________________________________ WITNESS____________________________

SIGNATURE OF PARENT OR GUARDIAN____

(for participants under the age of majority)

Appendix G – Health/Blood Questionnaire

Health/Blood Questionnaire

Name:
Date:
Please answer the following by checking **YES** or **NO**

I have read, understood, and completed this questionnaire. Any questions I had were answered to my full satisfaction.

1. Have you ever had a bleeding condition or a blood disease?		
2. Do you have Sickle Cell Anemia, or any other blood conditions?		
3. Have you ever had liver disease, viral hepatitis, or a positive test for hepatitis?		
4. Have you ever had malaria?		
5. Have you ever had, or come into contact with persons possessing a sexually-transmitted disease?		
6. In the past 12 months have you had a tattoo applied, ear or skin piercing, accidental needlestick, or come into contact with anyone else's blood?		
7. Have you ever used needles to take drugs, steroids, or anything else n prescribed by yuour doctor?		
8. In the past 12 months, have you had sex with anyone who has ever used needles to take drugs, steroids, or anything else not prescribed b their doctor?		
9. Have you ever had a positive test for the HIV/AIDS virus?		
10. In the past 12 months, have you had sex with anyone who has HIV/AIDS or has had a positive test for the HIV/AIDS virus?		

Name(Print)-

Signature- Date-

Appendix H – Figure 1. Resistance Training Protocol Blood Lactate Trends

Figure 1. Resistance Training Protocol Blood Lactate Trends

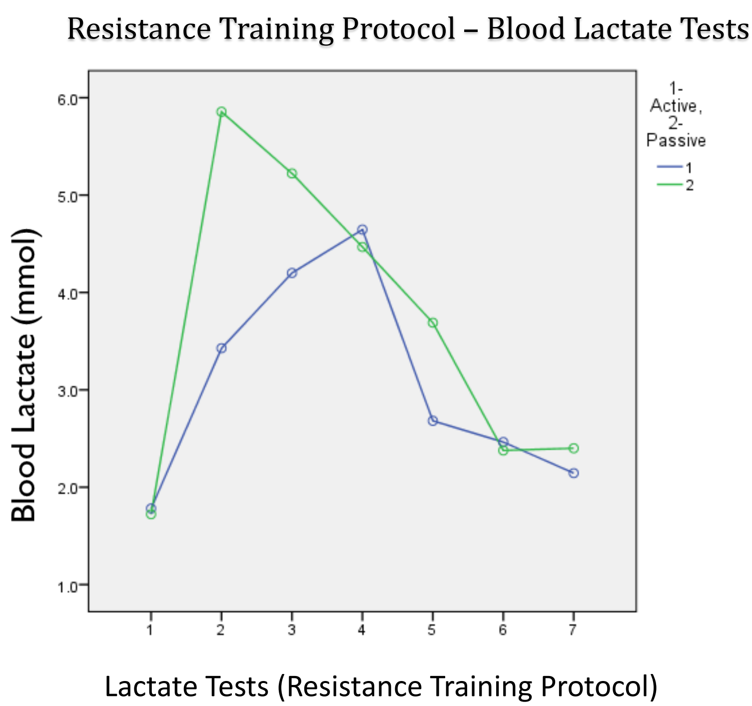

Figure 1 - Blood lactate value means for each test during the protocol including resting value(1), power cleans(2), barbell squat (3), barbell bench press (4), bent-over row(5), kettlebell swing(6), post-lactate test(7)